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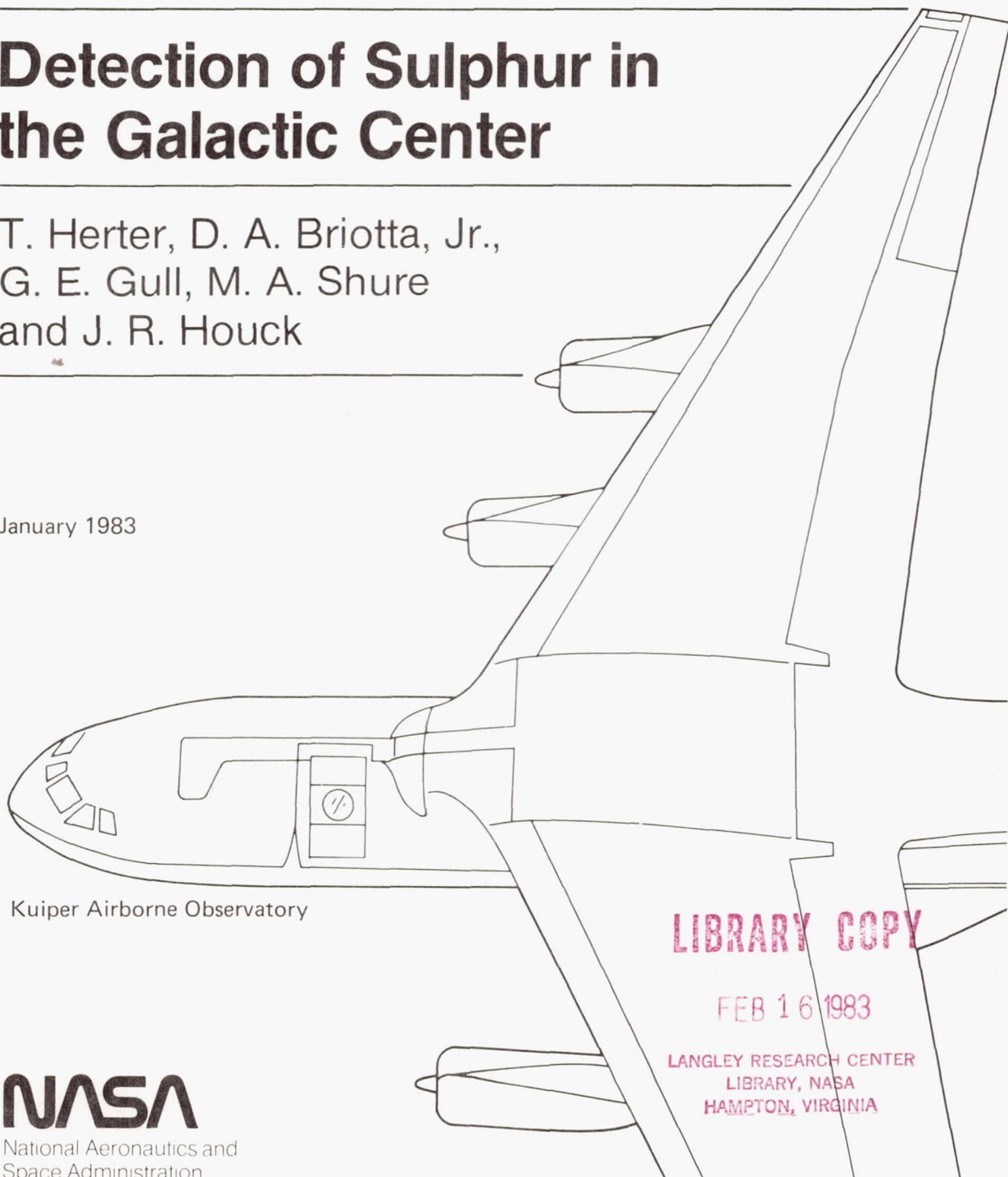
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ABSTRACT

A strong detection at the [SIII] 18.71 $\mu$ m line is reported for the Galactic Center region, Sgr A West. A line flux of  $1.7 \pm 0.2 \times 10^{-17} \text{ W cm}^{-2}$  is found for a 20-arc second beam-size measurement centered on IRS 1. A preliminary analysis indicates that the SIII abundance relative to hydrogen is consistent with the cosmic abundance of sulphur,  $1.6 \times 10^{-5}$ , if a filling factor of unity within the known clumps is assumed. However, the sulphur abundance in the Galactic Center may be as much as a factor of 3 overabundant if a filling factor of 0.03 is adopted, a value found to hold for some galactic HII regions.

## I. INTRODUCTION

The Galactic Center, Sgr A West, represents an inherently interesting region, rich in phenomena and perhaps unique as an object of study in our galaxy. Within the central parsec there exists a high luminosity HII region with clumps whose motions have projected line-of-sight velocities ranging from -250 km/sec to +250 km/sec, possibly indicating the presence of a massive object ( $\approx 10^6 M_{\odot}$ ) (cf. Oort 1977, Lacy et al. 1980, Gatley and Becklin 1981). Extreme visual obscuration,  $A_V \approx 30$  magnitudes, prohibits optical observations, hence the infrared and radio have been the dominant wavelength regimes used for studying this region. Much of the continuum infrared work has concentrated on delineating the nature and structure of the central few parsecs at different wavelengths. These investigations show the presence of numerous late-type stars as well as an extensive HII region complex with a total optical/ ultraviolet luminosity of  $\approx 10^7 L_{\odot}$  (Becklin and Neugebauer 1975; Gatley et al. 1977; Becklin et al. 1978; Rieke, Telesco and Harper 1978; Becklin, Gatley and Werner 1982).

Measurements of infrared forbidden line emission play a key role in the understanding of the dynamics and excitation of the Galactic Center. Although NeII ( $12.8 \mu\text{m}$ ) had been detected previously (Aitken, Jones and Penman 1974; Wollman et al. 1976, 1977; Willner

1978), it was not until recently that sufficient spatial and spectral resolution was achieved to coherently display the wealth of motions within the central parsec (Lacy et al. 1979, 1980).

While NeII has been the main dynamical probe of the central parsec, other ions have also been detected in the infrared and used as abundance and excitation indicators. These include ArIII (Lacy et al. 1980), ArII (Willner et al. 1979, Lester et al. 1981a), OIII (Dain et al. 1978, Watson et al. 1980), and OI (Lester et al. 1981b). These observations indicate a highly luminous, low-excitation HII region with  $L > 10^7 L_{\odot}$  and an effective temperature of  $\leq 35,000$  K for the exciting source or sources (Lacy et al. 1980). There is some indication that argon and neon may be overabundant (Lacy et al. 1980, Lester et al. 1981a). Additional information could be gained by observing other ions usually detected in HII regions such as SIII and SIV. Although there have been searches for both these ions (McCarthy et al 1980, Lacy et al. 1980), neither has been detected previously. Lacy et al. (1980) have placed a strong upper limit on the SIV abundance,  $\leq 0.08$  times the cosmic elemental abundance. However, the upper limit on the SIII abundance obtained by McCarthy et al. (1980) is consistent with the cosmic elemental abundance of sulphur.

The current investigation reports on a second search for SIII in Sgr A West with higher spectral resolution than that of McCarthy et al. (1980) and positive detection ( $>8\sigma$ ) of [SIII]  $18.71\mu\text{m}$  line emission.

## II. OBSERVATIONS

The observations reported here were made on June 18/19, 1982, using the 91-cm telescope of the Kuiper Airborne Observatory (KAO) on a flight from Moffett NAS, Mountain View, California, to Hickam AFB, Oahu, Hawaii. Flight altitude was in excess of 12.5 km with less than  $15\mu\text{m}$  of precipitable water vapor in the line of sight for both sources and calibrators. A dual-grating, liquid-helium-cooled spectrometer containing a three-element Si:Sb detector array was used for the measurements (Houck and Gull 1982). The resolution of the spectrometer (FWHM) is  $0.033\mu\text{m}$  at  $18.71\mu\text{m}$ . The beam size, when used on the KAO, is approximately  $20''$  in diameter on the sky. IRC+10420 and Callisto were used as calibrators. The flux of IRC+10420 is assumed to be  $2.4 \times 10^{-15} \text{ W cm}^{-2} \mu\text{m}^{-1}$  at  $18.7\mu\text{m}$  (Forrest, McCarthy and Houck 1979), while the brightness (and color) temperature of Callisto is taken to be  $146^\circ\text{K}$  at the time of the observations (Forrest, Houck and McCarthy 1980). The overall flux calibration is estimated to be accurate to  $\pm 15\%$ .

Nine data points were taken about the line position at a sampling interval of approximately two points per resolution element (FWHM). Figure 1 displays the relative position and beam size of the current measurement on the  $20\mu\text{m}$  map of Sgr A West obtained by Becklin et al. (1978). The resulting spectrum is shown in Figure 2. For these observations a chopper throw of 6 arc minutes nearly perpendicular to the galactic plane was employed. An observed continuum level of  $\approx 1.2 \times 10^{-15} \text{ W cm}^{-2} \mu\text{m}^{-1}$  is consistent with the flux of  $1.57 \pm 0.04 \times 10^{-15} \text{ W cm}^{-2} \mu\text{m}^{-1}$  observed at  $18.9\mu\text{m}$  by McCarthy et al. (1980) in a  $30''$  beam. The line flux of SIII at  $18.71\mu\text{m}$  is found to be  $1.7 \pm 0.2 \times 10^{-17} \text{ W cm}^{-2}$ , consistent with the upper limit of  $1.9 \times 10^{-17} \text{ W cm}^{-2}$  found by McCarthy et al. (1980). The measured line width of  $0.039 \pm 0.004\mu\text{m}$  is marginally broader than the instrumental resolution of  $0.033\mu\text{m}$ , and consistent with the velocities observed for NeII (Wollman et al. 1976; Lacy et al. 1979, 1980).

### III. IONIC ABUNDANCE

The relative ionic abundance of SIII can be obtained from the present measurements if we know (1) the column density of the ionized hydrogen in the beam, (2) the extinction at  $18.71\mu\text{m}$ , and (3) the temperature and density of the emitting region.

a) HII Column Density

Comparing the 6-cm VLA map of Brown, Johnston and Lo (1981) with Figure 1 indicates that of the sources which have significant radio emission, only sources 1, 2, 10 and 20 will be contained within our beam.

Including these point sources with the "corrected" 5 GHz fluxes of Brown, Johnston and Lo (1981) plus 50% of the extended ridge emission, they measure the total thermal radio emission appropriate for comparison with the current measurement should be approximately 6 Jys.

b) Extinction

Numerous authors have estimated the extinction to the stars and HII region at the Galactic Center; however, the most comprehensive determinations are those of Willner and Pipher (1983) who have measured  $\text{Br}\alpha$  and  $\text{Br}\gamma$  fluxes from 11 sources in the Galactic Center at better than 4" spatial resolution. They find that the extinction is fairly uniform with the possible exception of source 6 which appears to have a somewhat higher extinction. In particular, sources 2, 4, 5, 6 and 20 have 2.5, 2.5, 2.5, 4.0 and 2.3 magnitudes of extinction at  $2.17\mu\text{m}$  respectively. Since the relative radio strength of source 6 is small and it lies outside our beam (Brown, Johnston and Lo 1981), an extinction of 2.5 magnitudes at  $2.17\mu\text{m}$  will be adopted. Using the  $\text{Br}\gamma$  flux of Neugebauer et al. (1978) measured in a

32" beam and the adopted extinction, the predicted radio flux at 5 GHz is 8.2 Jy (Brocklehurst 1971, Giles 1977), for an assumed electron temperature of 5000 K (Rodriguez and Chaisson 1979). This estimate of the radio flux compares favorably with the previous estimate of the radio flux contained within a 20" beam. Adding up all the point sources expected to be contained within a 32" beam and including all of the extended ridge emission yields 11 Jys at 5 GHz (Brown, Johnston and Lo 1981). These comparisons give one an idea of the uncertainty in our estimate of the ionized hydrogen column density in our beam.

Willner and Pipher (1983) demonstrated that for the Galactic Center sources, with the possible exception of source 6, the extinction derived from Br $\alpha$  and Br $\gamma$  measurements agrees well with the extinction found from type I model fits to the silicate absorption feature (Gillett et al. 1975). These fits assume an underlying blackbody continuum attenuated by cold silicate dust. This result differs from most galactic HII regions which usually agree better with type II fits (cf. Herter et al. 1981). Type II fits assume an underlying Trapezium-like silicate emission. McCarthy et al. (1980) found, from modeling the 19 $\mu$ m silicate feature, optical depths at 18.9 $\mu$ m of 0.9 and 2.1 from type I and II fits respectively. Taking  $\tau_{18.9} = \tau_{18.7}$  and  $\tau_{18.7}/\tau_{2.17} \approx 0.6$  (Herter et al. 1981),

then 2.5 magnitudes of extinction at  $2.17\mu\text{m}$  yields  $\tau_{18.9} = 1.4$  which is midway between the estimates of the optical depth of McCarthy et al. (1980).

c) Electron Density and Temperature

The derived S III ionic abundance relative to hydrogen is  $1.3 \pm 0.2 \times 10^{-6}$  assuming  $\tau_{18.7} = 1.4$ , an rms electron density of  $20,000 \text{ cm}^{-3}$  (Brown, Johnston, and Lo 1981) and an electron temperature of 5000 K (Rodriguez and Chaisson 1979). We have used the transition probabilities and collision strengths compiled by Mendoza (1982). The above estimate does not include an error term for the uncertainty in the extinction correction. If  $\tau_{18.7}/\tau_{2.17}$  changes by 10%, then the resulting change in the derived ionic abundance is 14%. The cosmic elemental abundance of sulphur is  $1.6 \times 10^{-6}$  (Allen 1973). If the region is clumped on a scale smaller than the VLA beam size of Brown, Johnston and Lo (1981), then the S III ionic abundance will be higher. Filling factors, as found from S III lines for local H II regions, may be as small as 0.03 (Herter, et al. 1982a,b). Decreasing the filling factor to 0.03 increases the derived S III abundance by a factor of 3.

Rodriguez and Chaisson (1979) find an electron temperature of  $5000 \pm 1000^\circ\text{K}$  for Sgr A West. This is somewhat lower than that deduced for local H II regions which typically have  $T_e \approx 8000^\circ\text{K}$  (Silvergate and

Terzian 1979; Wilson, Pauls and Ziurys 1979; Mezger et al. 1979). A temperature as low as  $\approx 5000^\circ\text{K}$  is also consistent with the  $\text{Br}\alpha$ ,  $\text{Br}\gamma$  measurements of Willner and Pipher (1983). Increasing the assumed temperature to  $8000^\circ\text{K}$  only decreases the deduced sulphur abundance by about 15%.

The electron temperature and the abundances are not independent; increases in the abundance of heavy elements result in lower electron temperatures. A temperature of  $5000^\circ\text{K}$  implies a factor of 3 overabundance in coolants (cf. Mezger et al. 1979). If most sulphur is in the form of SIII as in the case of typical HII regions (cf. McCarthy, Forrest and Houck 1979; Herter, Helfer and Pipher 1982), and the sulphur/oxygen abundance ratio is cosmic, i.e., 0.024 (see, however, Talent and Dufour 1979), then the above analysis requires a filling factor of  $\approx 0.03$  for the Galactic Center. A similar analysis by Watson et al. (1980) for the [OIII]  $51.8\mu\text{m}$  line indicates a filling factor ranging from 1 to 0.01, depending on the relative amounts of the OII and OIII present. However, in such low-excitation objects the ratio of OII to OIII is a very strong function of the detailed excitation conditions. The filling factor as derived from SIII, however, is much less susceptible to excitation changes.

#### IV. FURTHER WORK

The wealth of ions now observed in Sgr A West make it feasible to attempt a synthesis of the data into a coherent framework. Because different infrared lines are sensitive indicators of density over a wide range of densities and because various line ratios are sensitive indicators of the excitation conditions, a consistent picture of abundances, electron densities and excitation in the Galactic Center can be developed. In a paper to be submitted to the main journal, a more detailed analysis of the implications of the currently available observations is explored (Herter and Houck 1983).

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L103.

## FIGURE CAPTIONS

Figure 1 - 20  $\mu$ m map of Sgr A West obtained by Becklin et al. (1978), by permission. Numbers are infrared sources. The thin circle centered on IRS 1 indicates the beam position and size (FWHM) of the current measurement.

Figure 2 - The 18.7  $\mu$ m spectrum of Sgr A West obtained with a 20" aperture centered on IRS 1. The resolution is  $\lambda/\Delta\lambda \approx 600$ .

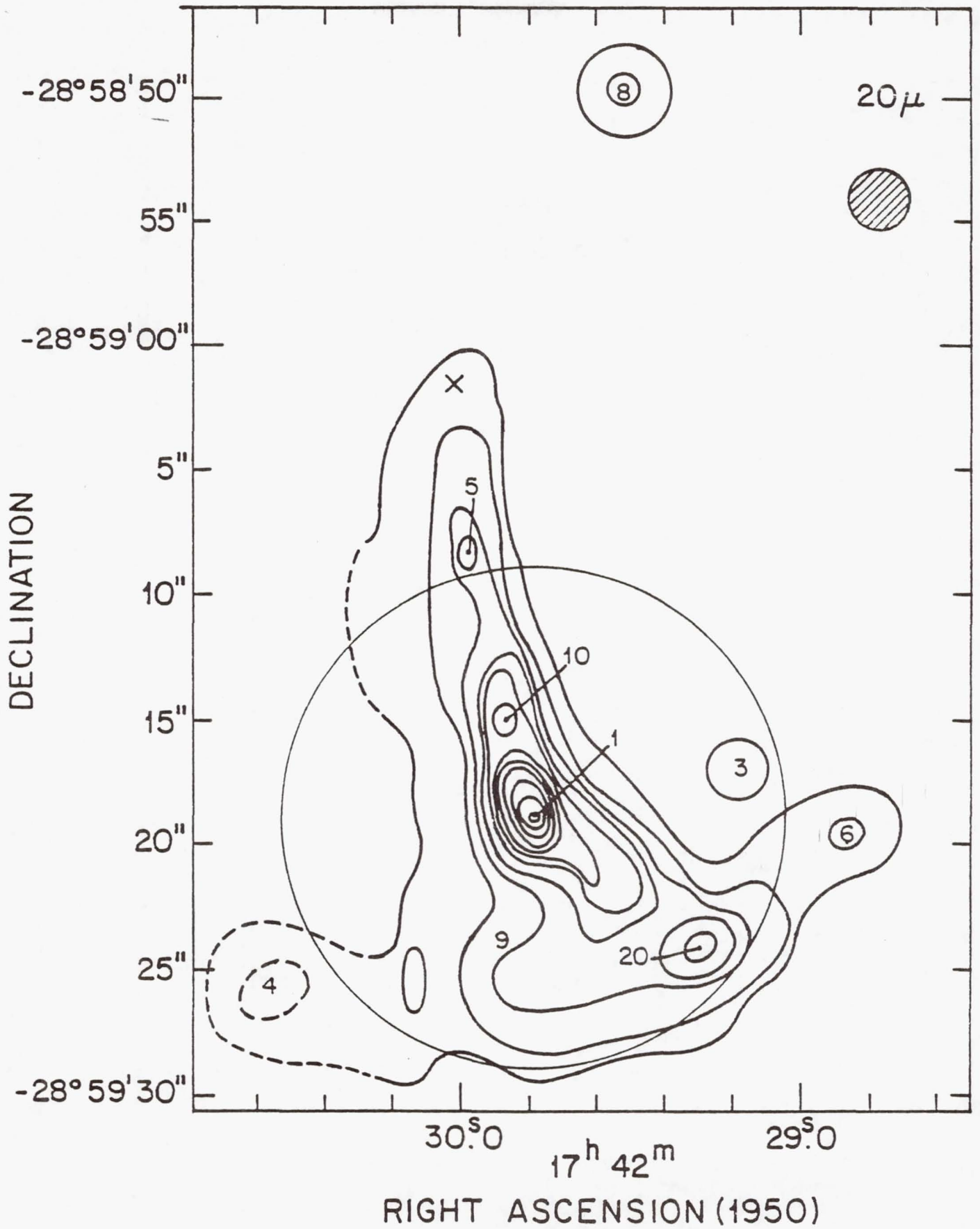


Figure 1

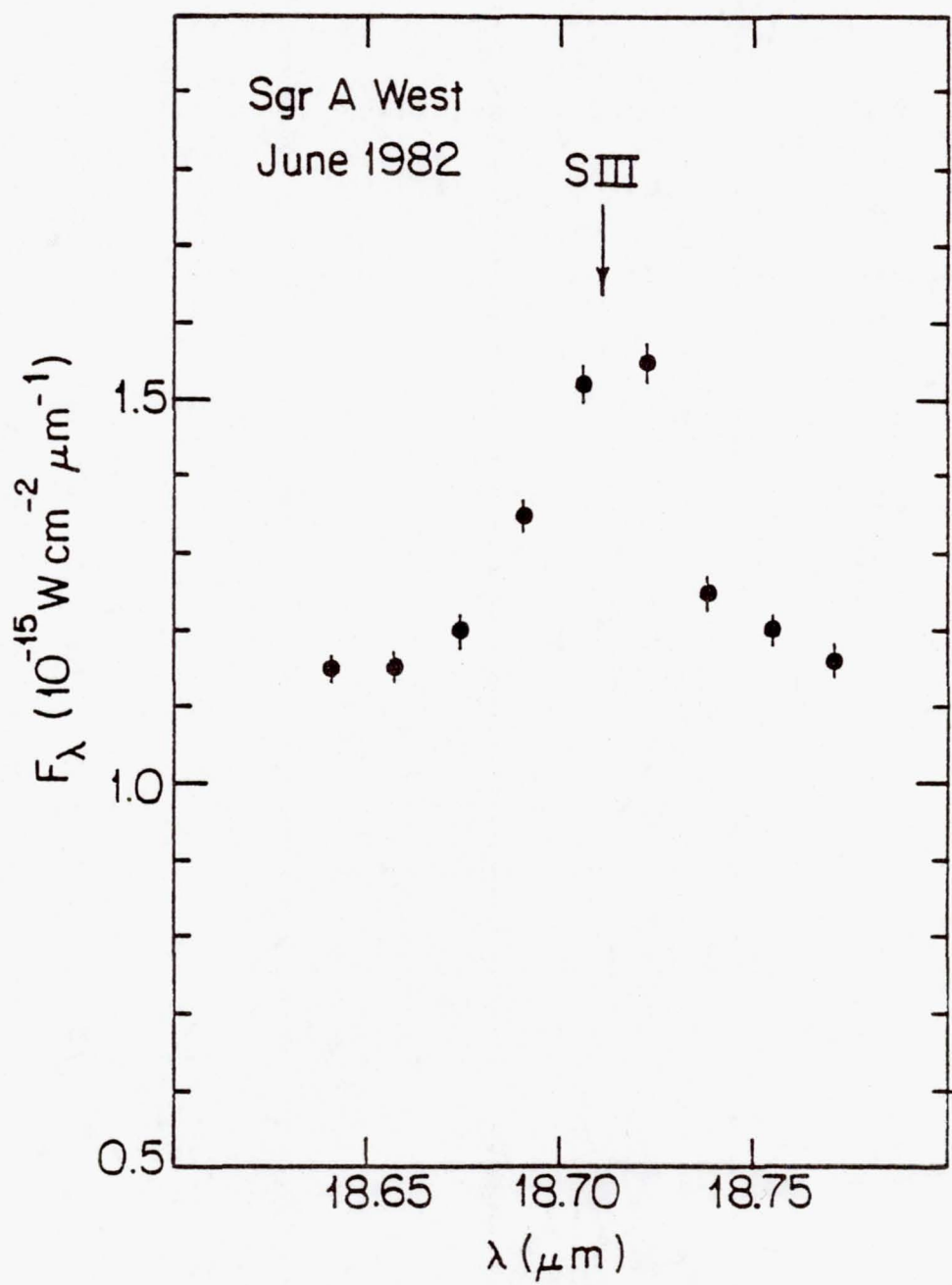


Figure 2

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